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Cotton production with SDI, LEPA, and spray irrigation in a thermally-limited climate

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Introduction

The Southern High Plains of Texas, centered at approximately Lubbock, is one of the major cotton-producing areas in the United States, contributing approximately 10-20 percent of the average 20 million bales of upland cotton produced in the nation (USDA-NASS, 2005; TDATASS, 2005).

In recent years, cotton production has expanded northward toward the Northern Texas Panhandle and Southwestern Kansas as an alternative to corn because cotton has only one half the irrigation requirement but has similar revenue potential as corn.

The primary limitation to cotton production where corn has traditionally been produced is the lack of growing degree days (heat units) and the lack of an industry infrastructure (gins, custom harvesters, etc.).

The other main limitation is of course water, insufficient and sporadic in-season rainfall, and high evaporative demand. Despite these limitations, showed that cotton production in this area is feasible, with lint yields and water use efficiencies comparable to those in more ideal climates

Pressurized irrigation systems such as mechanically moved and microirrigation can enhance cotton lint yield and water use efficiency compared to furrow (gravity) irrigation or dryland regimes, provided the pressurized system is properly designed and managed.

Mechanically moved systems have numerous variants of applicator packages,

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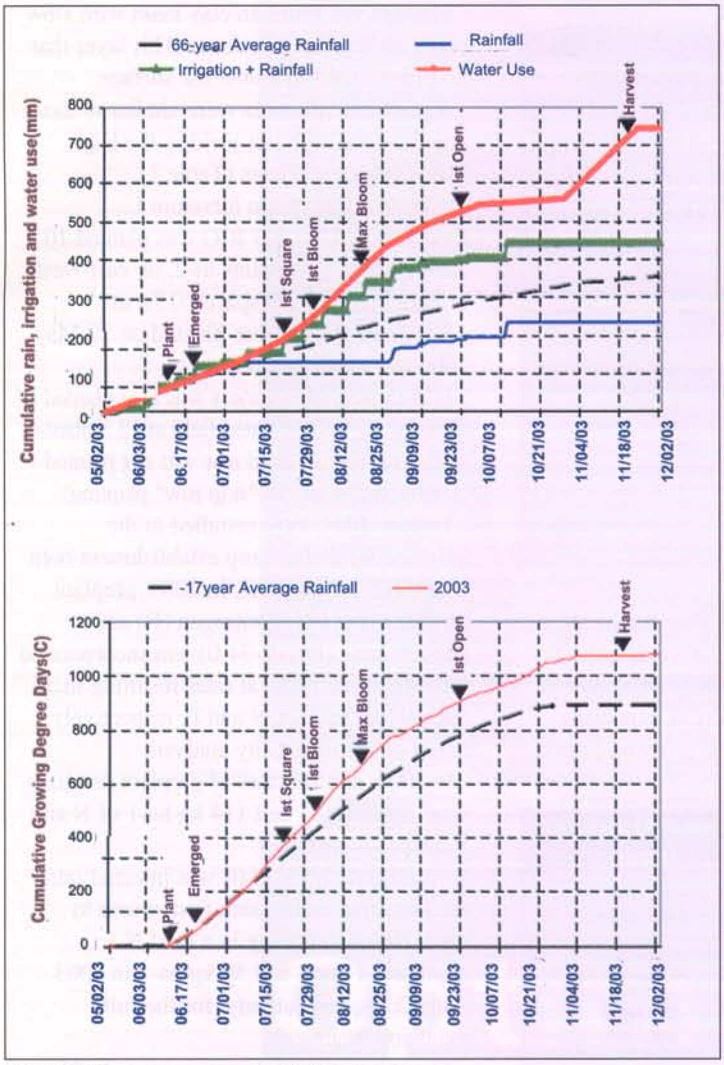

Fig 1. 2003 cotton season for full irrigation

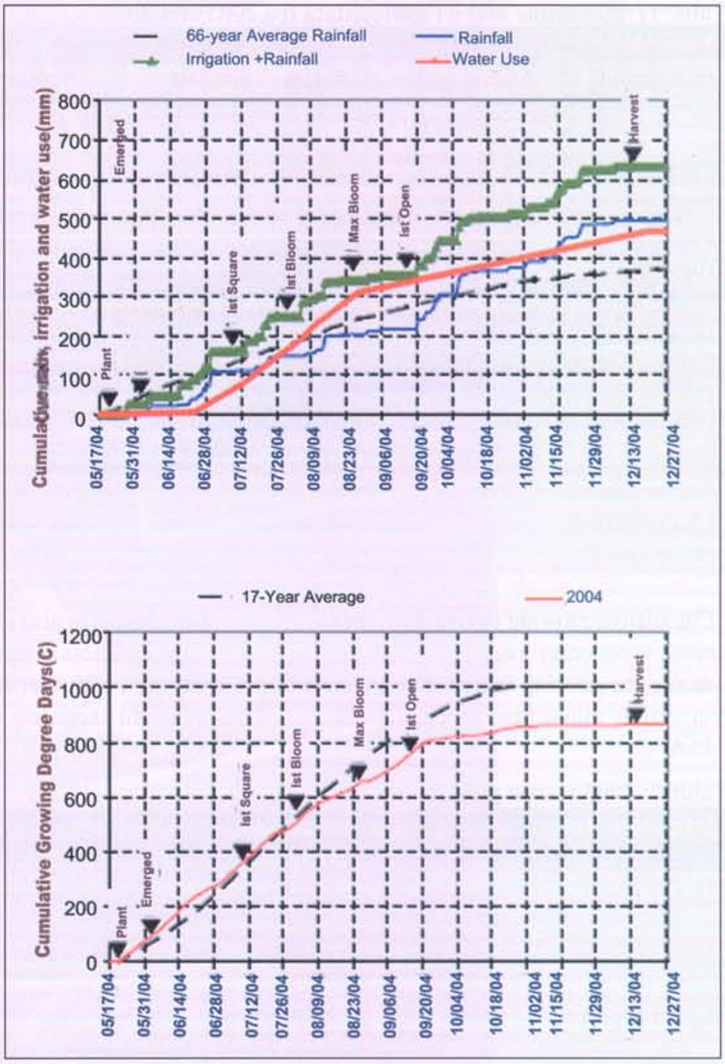

Fig 2. 2004 cotton season for full irrigation

with the more common configurations being mid- and low-elevation spray application (MESA and LESA, respectively) and LEPA (Low Energy Precision Applicator;)

Microirrigation, usually in the form of subsurface drip irrigation (SDI),

has been widely adopted by commercial cotton producers throughout the South Plains and Trans Pecos regions of Texas beginning in the early 1980s.

Although SDI has significantly greater initial costs than spray or LEPA systems, it has been documented to slightly outperform LEPA and spray in terms of lint yield, lint quality, and water use efficiency.

Similar trends have been reported for surface drip where laterals were placed in alternate furrows and each planted row

Analysis of four years of continuous monoculture cotton data at Halfway, Texas, concluded that SDI may not always provide economic returns as large as LEPA does; but this largely depended on system life, installation costs, pumping lift requirements, and hail damage that commonly occurs in West Texas.

There is a general perception by some cotton producers that SDI enhances seedling emergence and plant maturity due to reduced evaporative cooling compared to LEPA or spray, which is a critical consideration in a thermally limited environment and is seldom considered in economic analyses.

There is, however, limited data in direct support of this view. that cotton under SDI matured several days later than cotton under furrow irrigation.

The objectives of this study are to evaluate cotton yield, fiber quality, and maturity rates

This paper presents the results of the 2003 and 2004 growing seasons.

Procedure

An experiment was conducted during the 2003 and 2004 growing seasons using MESA, LESA, LEPA, and SDI to irrigate cotton at the USDA Conservation and Production Research Laboratory in Bushland, Texas (35° 11? N lat., 102° 06? W long. 1070 m elevation MSL).

The climate is semi-arid with a high evaporative demand of about 2,600 mm per year (Class A pan evaporation) and low precipitation averaging 470 mm per year.

Most of the evaporative demand and precipitation occur during the growing season (May to October) and average 1,550 mm and 320 mm, respectively.

Table 1. Agronomic and irrigation data fro 2003 and 2004.

Variable	2003	2004
Fertilizer applied	31 kg ha -1 preplant N 107 kg ha -1 preplant P 48 kg ha -1 irr N (I100) [a]	34 kg ha -1 preplant N 114 kg ha -1 preplant P 50 kg ha -1 irr N (I100) [a]
Cotton variety	paymaster 2280 BG, RR	paymaster 2280 BG, RR
Plant density	17 plants m-2	19 plants m -2
Planting date	10 Jun [0]	20-May
Harvest date	21-Nov	14-Dec
I0 preplant irrigation	200mm	25mm
I25 preplant irrigation	200mm	25mm
I50 preplant irrigation	175mm	25mm
I75 preplant irrigation	125mm	25mm
I100 preplant irrigation	100mm	25mm
Irrigation to set furrow dikes	9-Jul	18-Jun
First treatment irrigation	21-Jul	14-Jul
Last irrigation	20-Aug	8-Aug
Precipitation	230mm1	495mm

Cumulative growing degree days (heat units) for cotton average 1,050 °Cdays during the growing season (mean daily air temperature minus base temperature of 15.6 °C.

The climate is also characterized by strong regional advection from the south and southwest, with average daily wind runs at 2 m height exceeding 460 km, especially during the early part of the growing season.

Table 2: 2003 season yield, water use

Irrigation Rate [a]	Irrigation Method	Lint Yield (kg ha^{-1})	Seasonal Water Use (mm)
I_{25} (71 mm)	MESA	213b	477b
	LESA	288ab	495ab
	LEPA	362ab	494ab
	SDI	491a	530a
I_{50} (117 mm)	MESA	536b	604b
	LESA	575ab	582ab
	LEPA	685ab	629ab
	SDI	844a	627a
I_{75} (165 mm)	MESA	1001b	705b
	LESA	984ab	685ab
	LEPA	1149ab	701ab
	SDI	1082a	714a
I_{100} (211 mm)	MESA	1229b	752b
	LESA	1208ab	754ab
	LEPA	1153ab	727ab
	SDI	1150a	725a
Irrigation Rate Averages			
I_0 (25 mm)	--	196d	437e
I_{25} (71 mm)	--	339d	499d
I_{50} (117 mm)	--	660c	610c
I_{75} (165 mm)	--	1054b	701b
I_{100} (211 mm)	--	1185a	739a
Irrigation Method Averages			
	MESA	745a	635a
	LESA	764a	629a
	LEPA	837a	638a
	SDI	892a	649a

The soil is a Pullman clay loam with slow permeability due to a dense B21t layer that is 0.15- to 0.40-m below the surface.

Agronomic practices were similar to those practiced for high lint yield in the High Plains region of Texas (Table 1).

Cotton (Gossypium hirsutum L., Paymaster3 2280 BG RR) was planted 10 June 2003 at 17.3 plants m-2, on east-west oriented raised beds spaced 0.76 m.

The same variety was planted on 20 May 2004 at 19.0 plants m-2.

In 2004 only, this variety was also planted in an adjacent, non-irrigated field at 12.5 plants m-2, where every third row was not planted (known regionally as "skip row" planting).

Furrow dikes were installed in the irrigated field after crop establishment both years to control runoff. In 2003, preplant fertilizer containing nitrogen (N) and phosphorous (P) (10-34-0) was incorporated into the raised beds, at rates resulting in 31 and 107 kg ha-1 of N and P, respectively, based on a soil fertility analysis.

In 2004, similar rates of preplant fertilizer were applied (34 and 114 kg ha-1 of N and P, respectively).

Additional N (32-0-0) was injected into the irrigation water from first square to early bloom, resulting in a total N application of 48 and 50 kg ha-1 in 2003 and 2004, respectively, for the full irrigation treatment.

The experimental design consisted of four irrigation methods (MESA, LESA, LEPA, SDI,), and five irrigation rates (I0, I25, I50, I75, and I100).

The I100 rate was sufficient to prevent yield-limiting soil water deficits from developing, and the subscripts are the percentage of irrigation applied relative to the full (I100) irrigation rate. The I100 rate was based on soil water measurements with neutron scattering to 2.4-m depth.

Early in the season, irrigation water was applied when soil water measurements indicated a deficit of 25 mm

The statistical design was a variant of the split-block design where irrigation methods were in the direction of travel of a three-span lateral move system, and irrigation rates were perpendicular to the direction of travel.

Each span of the linear move system constituted a complete block (i.e., replicated

Table 3: 2004 season yield, water use

Irrigation Rate [a]	Irrigation Method	Lint Yield (kg ha^{-1})	Seasonal Water Use (mm)
I25 (72 mm)	MESA	622a	355c
	LESA	579a	390bc
	LEPA	586a	428a
	SDI	648a	404ab
I50 (94 mm)	MESA	594b	402b
	LESA	563b	411b
	LEPA	592b	406b
	SDI	681a	452a
I75 (115 mm)	MESA	644b	434ab
	LESA	637b	448a
	LEPA	673b	437ab
	SDI	779a	410b
I100 (137 mm)	MESA	684b	461a
	LESA	675b	489a
	LEPA	733b	462a
	SDI	879a	455a
Irrigation Rate Averages			
Isr (0 mm)	---	594bc	---
I0 (50mm)	---	533c	367c
I25 (72mm)	---	609c	394c
I50 (94mm)	---	607c	418b
I75 (115mm)	---	683ab	432b
I100 (137mm)	---	743a	467a
Irrigation Method Averages			
---	MESA	636b	413a
---	LESA	614b	434a
---	LEPA	646b	433a
---	SDI	747a	430a

three times), and irrigation methods were randomized within each block.

Plots were 25 m long by 9 m wide with 12 rows each, and 5 m planted borders separated irrigation rate strips.

Irrigation treatment levels were controlled by varying the speed of the lateral-move system for the spray and LEPA methods, and by different emitter flow and spacing for the SDI method. All treatments were irrigated uniformly with MESA at the I100 level until furrow dikes were installed to ensure crop establishment.

During the season, soil water was measured volumetrically near the center of each plot on a weekly basis by neutron attenuation to 2.4-m depth in 0.2-m increments.

The gravimetric samples were used to compute seasonal water use (irrigation + rainfall + change in soil water), and the neutron measurements were used to verify that irrigation was sufficient so that no water deficits developed in the I100 treatment.

Seed cotton was harvested following hand sampling with a commercial cotton stripper, and stalks were shredded and rotary-tilled into the beds.

Results and Discussion

Rainfall, Irrigation, and Growing Degree Days

The 2003 and 2004 growing seasons contrasted in that 2003 had below average rainfall and above-average air temperatures (Figure 1) and vice-versa for 2004 (Figure 2). In 2003, in season rainfall was near the 66-year average until around 30 June, which allowed in-season irrigations to be delayed until 8 July as there was sufficient water stored in the soil profile.

Cumulative growing degree days (15.6 °C base temperature;) from planting (10 June) to harvest (21 November) in 2003 totaled 1076 °C-days.

The first open boll in the I100 treatment was not observed until 22 September (900 °C-days), but nearly all bolls were open by 20 October, and the first frost occurred on 26 October.

Additional frost events defoliated all remaining vegetative matter so that chemical defoliant was not required by harvest (21 November).

In 2004, in-season rainfall was unusually frequent but remained slightly below the 66 year average until late September, after which precipitation was above average for the remainder of the year.

Precipitation frequency continued to be unusually high for the remainder of the season, and the crop could not be harvested until 14 December.

Crop Response to Irrigation Methods and Rates

No differences in maturity rates (open harvestable bolls) were noted for any irrigation method (MESA, LESA, LEPA, or SDI) in both the 2003 and 2004 seasons.

Differences in maturity rates appeared to vary primarily with irrigation rates, which had the greatest soil water depletion, and proceeding through each subsequent level.

Crop response in terms of lint yield, seasonal water use, water use efficiency (WUE), irrigation water use efficiency (IWUE), fiber quality parameters, discount or premium, and gross return were evaluated for irrigation rates and methods for 2003 and 2004.

The cooler and wetter conditions of 2004 (Table 3) resulted in less seasonal water use, (Table 2).

Conclusion

Cotton maturity was influenced by soil water depletion (reflected by irrigation rate) rather than irrigation method.

Fiber quality was usually better with SDI in both years, which is becoming increasingly important in the global market. For a given irrigation rate, seasonal water use differences were not always significant or consistent between irrigation methods, with seasonal water use sometimes being greater with SDI, possibly due to enhanced plant vigor.

In both years, significant (but different) relationships were observed between lint yield and seasonal water use.